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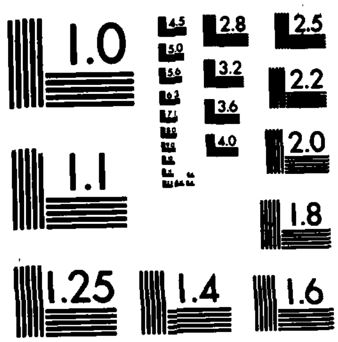

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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

NEW FUNCTIONAL ELEMENTS

by

Munenori Sakamoto

FOREIGN TECHNOLOGY DIVISION

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Table of Contents

GRAPHICS DISCLAIMER

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On the Future Basic Industrial Technology Research and Development System

1. Purpose of this System

The importance of furthering technological development in Japan, which is a resource-poor country, has gradually increased with the era of the Energy Crisis. In particular, research and development of indispensable basic technology for the establishment of future industries, such as aviation and space, data processing, new energy developments, bioindustries, etc., whose growth in the 1990's is anticipated, has become an urgent problem in Japan, which has followed advanced countries of the world without relying on imported technology to a great extent. These technologies are those in which a break through has been made. These technologies are having a great impact. In addition to the establishment of new industries, these technologies are expected to play a large role in improvement of existing industries, break-down of resource and energy restrictions, realization of a clean, unpolluted society, and contribution to an international community.

Therefore, the Ministry of International Trade and Industry has combined the 3 points of 1 national action and potential, 2 a large amount of funds, and 3 planned and effective development systems in order to reinforce industrial technological research and development in Japan and plans to carry out important research and development under the "Future Basic Industrial Technology Research and Development System" in 1981.

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*Translator's note: numbers in margins refer to foreign page number.

2. **Research and Development Themes of this System**

Research and development in this system is progressing under the following 12 themes, which are classified under the 3 divisions of new materials, biotechnology, and new functional elements.

New Materials
- fine ceramics
- highly efficient diagram materials
- conductive polymer materials
- high crystal polymer materials
- highly efficient crystal control alloys
- composite materials

Biotechnology
- bioreactors (technology used in industrial biological reactions)
- mass cell cultivation technology
- technology used in DNA rearrangement

New Functional Elements
- ultralattice elements
- 3 dimensional circuit elements
- environment-proof elements

3. Execution of this System and Development System

This system proceeded with research and development under joint cooperation of industry, sciences, and government (testing labs). In order to carry out planned and effective research and development for a period of 8-10 years, as a rule, several research and development methods will be employed and research and development will be carried out in 3 periods, 1-3. An evaluation committee consisting of specialists in each field will evaluate the research and development conditions and results.

4. Budget

The budget for the 10 year period has been set at approximately 100,000,000,000 yen. The 1981 and 1982 budgets are as follow.

	1982	1981
general accounts	4,790,000,000 yen	2,710,000,000 yen
new materials	2,600,000,000 yen	1,360,000,000 yen
biotechnology	1,040,000,000 yen	680,000,000 yen
new functional elements	1,130,000,000 yen	670,000,000 yen

Research and Development on New Functional Elements /37

1. New Functional Elements

New functional elements are defined as "elements which have rapidly improved on the functions of conventional semiconductor elements, or elements having new functions not seen thus far." Several devices are relevant within this type of summary. However, of the new functional elements basic to electronics and mechanics in the 1990's, research and development is progressing in this research and development system on the 3 themes of "ultralattice elements","three-dimensional circuit elements", and "environment-proof elements", which have had a great technological impact and are very innovative.

In its basic stages, there is still a basic difference in quality between semiconductor technology standards in Japan and in European countries. One reason for this seems to be the recent Japan-U.S. semiconductor competition. Consequently, development of Japanese technology in the field of new functional elements will be necessary in order to establish a "technological nation" and to establish a technologically advanced industry.

2. New Functional Element Research and Development System

Research and development of new functional elements is being carried out mainly through cooperation of corporations and research institutes (10 companies of Hitachi, Nippon Denki, Tokyo Shibaura Denki, Fujitsu, Mitsubishi, Fukashi Denki Kogyo, Matsushita Denshi Sangyo, Sumitomo Denki Kogyo, Mitsuyo Denki, and Shyābu*). The Electronics Technology Institute is carrying out the basic research.

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*Translator's note: term unknown; transliteration of Japanese phonetic characters.

Ultralattice Element Research and Development

1. Necessity of Research and Development

(1) Saturation of heat production and electronic speed have become problems in the advancement of semiconductor elements due to past miniaturization.

(2) Absolute dimensional accuracy is necessary in the new high speed elements. Moreover, technology for manufacturing structures including various crystals in small crystal spaces is necessary.

(3) There was a limit to the use of crystals with conventional structures because of their physical constants. Therefore, materials made by accurately planning and controlling their combination with the purpose of the element are necessary.

2. Ultralattice Elements

The term "ultralattice elements" has not been established. However, they are defined as "an element having a structure where the atoms in normal crystals are arranged periodically in lattice form and (a large) periodicity exceeding the lattice constants are artificially formed." There are many elements that fit into this type of outline [1]. However, in this theme, ultralattice research and development is being carried out on the 2 fields of "ultralattice functional elements" and "ultrastructural lattice elements" for the sake of convenience.

3. Ultralattice Functional Elements

(1) Vertical Ultralattice Elements

These are the negative resistance elements introduced by Professor Ezaki of IBM in 1970. In general, these elements are often called "ultralattice elements." Their basic structure is shown in Figure 1. The structural elements in Figure 1 are made into a vertical ultralattice element for a comparison with Figure 2. In a conventional semiconductor crystal, for instance a GaAs crystal, the Ga and As atoms are systemattically arranged in the period of several A. However, the electron transport phenomenon in this type of crystal is very different

from the phenomenon inside a vacuum. Assuming sufficient acceleration of electrons within the crystal without dispersion based on a direct current field, a peculiar phenomenon is produced due to the periodic potential interference effects of the crystal lattice and the sinuosity of the electrons. This is sometimes called the property of negative resistance. Electrons accelerated by the electrical field gradually slow down when they reach the region where negative resistance in terms of energy is produced. When they finally reach the top of the energy band, Bragg reflection is produced and electrons are reflected and accelerate in the opposite direction. However, this is the opposite direction from the original electrical field and the electrons gradually slow down again. The electrons are reversed again an accelerate in the direction of the electrical field. Electrons in a crystal continue back and forth movements along a certain distance in the same phase (this is called Bloch vibration). An ultra high frequency current flows to the outer terminal.

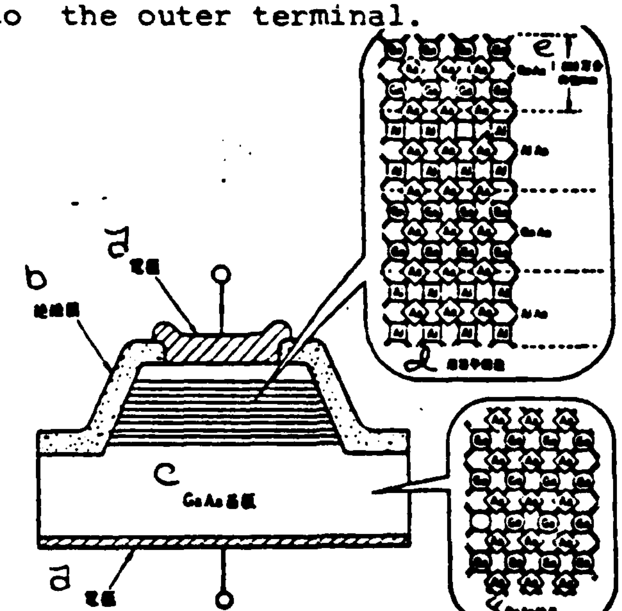


Figure 1 Outline of Vertical Ultralattice Element

Key: a. electrode b. insulating membrane
c. GaAs substrate d. ultralattice structure
e. (illegible) f. GaAs crystal

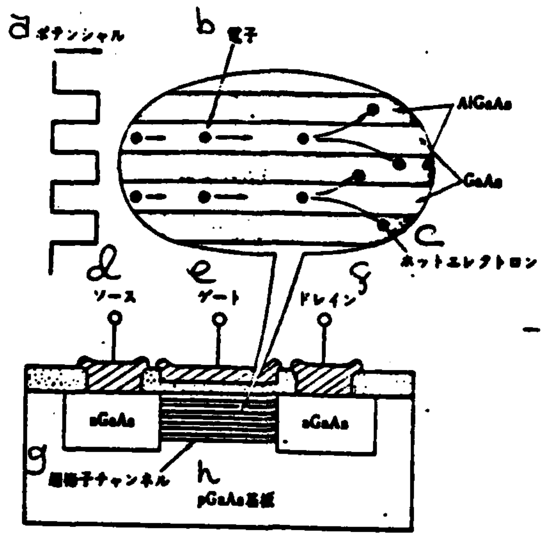


Figure 2 Outline of a Horizontal Ultralattice Element (Hot Electron Element)

Key: a. potential b. electron c. hot electron
d. source e. gate f. drain
g. ultralattice channel
h. pGaAs substrate

However, although it is theoretically possible, it is difficult to realize this phenomenon using already existing /38
semiconductor crystals. This is due to the fact that since the electronic energy necessary for producing this type of negative resistance is too large with conventional semiconductor crystals, electrons scatter with lattice vibrations and impurity atoms prior to acceleration and therefore, they cannot accelerate up to the top part of the energy band.

In order to overcome this difficulty, Professor Ezaki suggested that a periodic potential with a sufficiently large period in comparison to the lattice constant of the mother crystal be established to make the electronic energy necessary for producing this negative energy small by dividing the energy band into minizones. As shown in Figure 1, crystals having different band structures, such as GaAs and AlAs, are formed by periodic heteroepitaxial growth over several ten to several thousand layers with a thickness less than

de Broglie wavelengths (several 10 to 100 Å). It has become possible to manufacture this fine structure with the development of molecular beam epitaxial crystal growth (MBE). The average freedom of movement of electrons within semiconductor crystals (distance at which they can move without scattering) is several hundred to several thousand A. Therefore, electrons moving perpendicular to the ultralattice structure shown in Figure 1 are affected by periodic potential without being scattered for at least several periods. During this time, electrons are accelerated up to the energy region fulfilling the Bragg reflection condition and are then accelerated in the opposite direction.

If this type of negative resistance is obtained, it is anticipated that a basic role is played in realizing the active functions of oscillation, amplification, and switching and that operation speed will be very small. In contrast to the fact that in the case of conventional gun diodes and impart diodes the maximum oscillation frequency is 100 GHz, it is estimated that an oscillation frequency of 1,00 GHz or more is possible when Bloch vibrations from this ultralattice structure are employed. Figure 1 is an example of a 2 terminal element. However, when used in amplification elements, etc., the addition of a 3 number control electrode terminal may be necessary.

(2) Horizontal Ultralattice Elements

A multilayer heterobonded structure is used. However, an element where the current flows parallel to the connection is also being considered. An outline is shown in Figure 2. If the element shown in Figure 1 is a vertical ultralattice element, Figure 1 may be called a vertical ultralattice element. However, the operation theory is different. For instance, as shown in Figure 2, when a parallel electrical field is applied to an ultralattice structure where heteroepitaxial growth of materials with a large mobility, such as GaAs, and materials with a small mobility, such as AlGaAs, occurs, electrons which initially move to the base of the GaAs conduction band appear on the AlGaAs side with the development of a hot electron state when they are sufficiently accelerated. However, mobility on the AlGaAs side is low and therefore, the electrons suddenly slow down. Consequently, a minute load resistance is produced for the

current-voltage property at this time and it is assumed that oscillation and amplification become possible using this condition. Figure 1 is the case of pure negative resistance due to Bloch vibrations and Figure 2 is the case of differential negative resistance. Although the accuracy of this meaning may be poor, it seems that the realization of the case in Figure 2 is simpler.

In addition, it seems that 3 or more types of materials, such as ABCABC, may be used with this type of periodic structure and a new function is produced as a result of periodic lamination of materials with very different band structures, such as GaSb and In As [1].

4. Ultrastructural Lattice Elements

High speed was planned by reducing channel length through miniaturization in order to improve the operation rate of conventional elements, such as MOS transistors. /39

However, assuming a transistor with a channel length of 1 μm or less, the method for reducing dimensions with this type of structure were limited by the occurrence of punch cells and hot electrons. The structural elements shown in Figure 3 has been suggested as one break through to this problem. This element is one where the movement of electrons is controlled because a control electrode is inserted between the anode and cathode with the distance between the anode and cathode in the semiconductor crystal being less than the average freedom of movement of the electrons. In elements with conventional dimensions, the electrons moving through the semiconductor crystal are scattered by lattice vibrations and impurity atoms. Therefore, speed becomes saturated. However, the distance between the anode and cathode is the structural element in Figure 3 is less than the average freedom of movement of the electrons and therefore, the electrons can move without colliding (ballistic effect). Operation speed is very fast, at an estimated 1,000 GHz. This type of element displays triode operation and it is estimated that analogue operation at a high ouput can be realized with low heat generation.

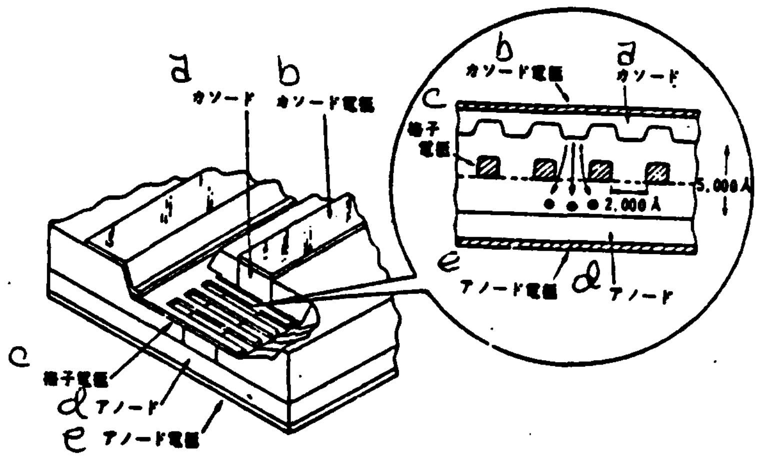


Figure 3 Outline of an Ultrastructural Lattice Element

Key: a. cathode b. cathode electrode c. lattice electrode d. anode e. anode electrode

5. Other Ultralattice Elements

In this research and development the 2 aforementioned types of elements, "ultralattice functional element" and "ultrastructural lattice element" were studied as basic types of ultralattice elements. However, other new elements, such as the 1 dimensional high mobility element [2], wide gap emitter transistor [3], tunneling hot electron element [4], etc., have been placed in the category of future ultralattice elements. Research and development may be carried out on these elements in the future.

6. Details and Objectives of Research and Development

Research and Developments will progress for 10 years until 1990 with importance placed on precision controlled growth technology of ultrathin membranes, studies on ultralattice materials, property evaluation technology, process technology, element design and evaluation technology, etc.

There are many theoretical and technological unknowns in the research and development of ultralattice elements. Standardization of basic forms and properties of elements in the next 10 years will be accompanied by many difficulties. Therefore, Table 1 gives several items which are technological objectives necessary to the materialization of the aforementioned ultralattice elements.

Table 1 Objectives and Types of Ultralattice Elements

type	objective
ultralattice functional element	making layers a single atom layer thickness making boundary density $10^9 cm^{-2}$ or less
ultrastructural lattice elements	making impurity transfer region 10 A or less making the anode-cathode distance 5000 A or less and inserting a control electrode between the anode and cathode

7. Ultralattice Element Research and Development System

Research and development on ultralattice functional element technology and ultrastructural lattice element technology has been recontracted to Fujitsu, Sumitomo Denko, and Hitachi by the New Functional Element Committee. The Electronics Technology Research Institute will be in charge of ultralattice element basic technology.

Research and Development on Three Dimensional Circuit Elements

1. Necessity of Research and Development

Technological innovation in semiconductor production has been remarkable. In particular, the degree of integration of silicon integrated circuits has continued to increase for 20 years since 1960 at an annual rate of 200%. The main thrust of improvements in this integration has been improvement of devices and circuits, increase in tape area and pattern miniaturization. In the future the main innovations will probably be expansion of tape area and miniaturization technology in order to approach the limits of simplification with the development of a 1 transistor memory. The minimum wire width with the 64 k bit DRAM, which is also called the pathway to super LSI and is being marketed in Japan, is 3 μm. However, basic development is being carried out on miniaturization technology for a minimum wire width of 0.5-1.5 μm. Basic miniaturization technology will be established over the next few years. Practical application of elements with a 1 M bit/chip degree of integration was realized in the last half of the 1980's.

Nevertheless, future methods for reducing conventional electronic structures will be theoretically and technologically limited by the development of hot electrons, source drain, and impurities. Therefore, it seems that there will be a saturation of integration in the 1990's. Consequently, the method whereby the degree of integration is quickly improved by multilayering seems to be one effective response. A comparison of the improvement in conventional 2 dimensional LSI integration and estimates of future 3 dimensional circuit element integration are shown in Figure 4.

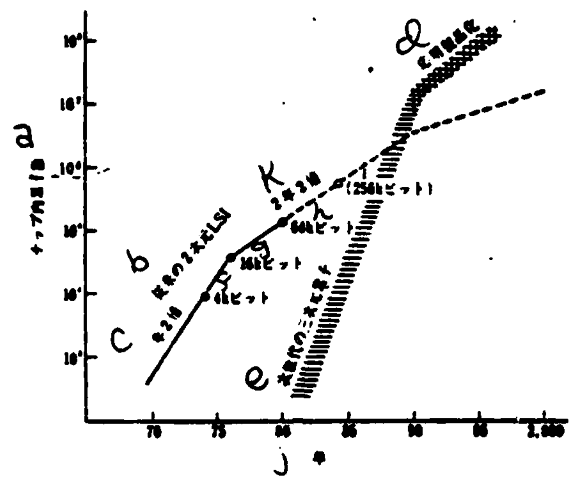


Figure 4 Conventional 2 Dimensional
LSI and Future 3 Dimensional Circuit
Element Integration

Key: a. number of elements in a chip
b. conventional 2 dimensional LSI
c. annual rate of 200%
d. production of goods for practical application
e. future 3 dimensional elements
f. 4 k bit
g. 16 k bit
h. 64 k bit
i. (256 k bit)
j. years
k. 200% in 2 years

2. A Method for Forming a Multilayer Structure

An oultine of a method for forming a multilayered structure for IC is shown in Figure 5.

1 The 1st LSI layer is formed using a silicon substrate or sapphire substrate. Based on later considerations of this process, a metal with a high melting point, etc. is necessary for the electrode materials in this case. Moreover, a method for reducing surface irregularities as much as possible is also essential.

2 An SiO_2 layer is formed with CVD, etc.

3 The SiO_2 layer is etched in an island-shape. When necessary, grooves for graphoepitaxy are simultaneously made.

4 Poly Si is applied by CVD and formed into an island shape.

5 Single poly Si crystals are made with laser or electron beam annealing.

6 Impurities are selectively enlarged at low temperatures using ion injection, etc. and a source drain region is formed.

7 2nd layer electrode wiring is carried out. Solid wiring with the 1st layer is simultaneously carried out at this time.

An Ic multilayered structure is made by repeating the aforementioned process. Research and development has been carried out on the single crystallization method, which employs beam annealing technology, using silicon. However, the prospect of using this technology for compound semiconductors is not good. Nevertheless, it seems that compound semiconductors will be used in the topmost layer of layered structures. Consequently, the development of a technology for forming a single crystal insulating layer is a very important problem.

3. Concrete Elements

The concrete form of 3 dimensional circuit elements can be divided into "layered high density integrated elements" and layered multifunctional integrated elements. Research and development on a basic technology for realizing these two elements is being carried out.

(1) Layered High Density Integration Elements

Circuit logic and memory elements are 3 dimensionally arranged and connected to each semiconductor active layer,

placed on top of one another with an insulating layer in between, to increase integration. An outline of memory element integration is shown in Figure 6. Integration is simply increased with this element. Moreover, signal transmission between layers is rapid and a GaAs, etc. control processor is used for the topmost layer. Therefore, this element is important because of the anticipated increase in elementfunctions.

(2) Layered Multifunctional Integration Elements

circuit elements having various functions, including a signal conversion function and sensor functions, are connected to each active semiconductor layer, which are laminated into many layers with insulating layers in between, for composite function integration. As shown in Figure 7, this consists of an electrical source and cooling section, memory section, main processor section, series processing section, etc. Moreover, an intelligent image processor having photoelectric conversion properties, such as CCD, and a large capacity data processing I/O intelligent terminal will be located on the topmost layer.

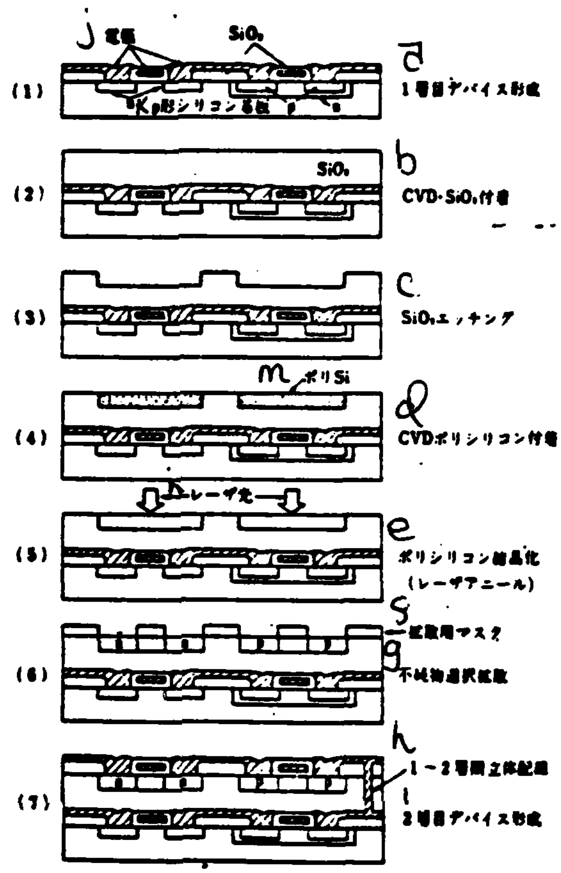


Figure 5 Outline of IC Layering Process

Key: a. 1st layer device formation b. CVD-SiO_2 deposition
c. SiO_2 etching d. CVD polysilicon deposition
e. polysilicon crystallization (laser annealing)
f. mask for enlargement g. impurity selection and enlargement
h. solid wiring between 1st and 2nd layers
i. 2nd layer device formed j. electrodes
k. p-type silicon substrate
m. poly Si n. laser light

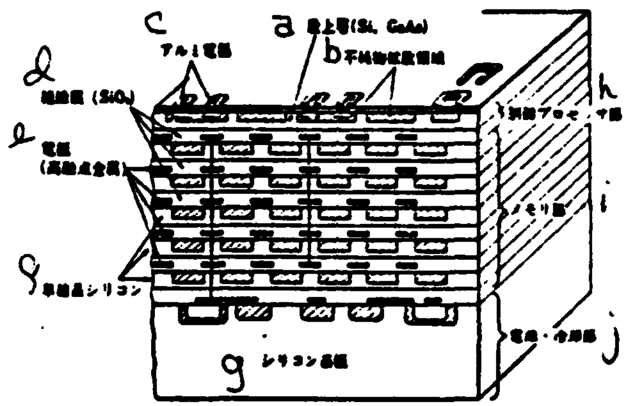
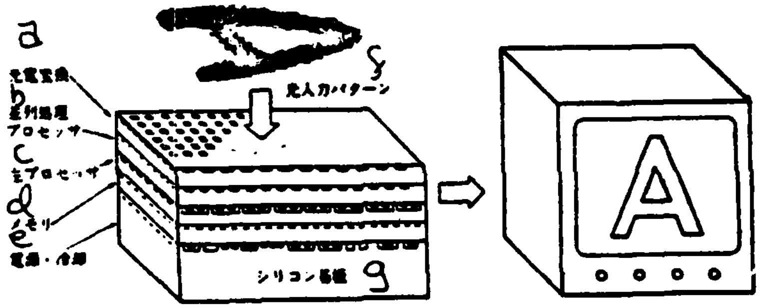


Figure 6 Layered High Density Integration Memory

(8-10 layers, 16 M bits/chip)

Key: a. topmost layer (Si, GaAs)

- b. impurity enlargement region
- c. aluminum electrodes
- d. insulating film (SiO_2)
- e. electrodes (metals with high boiling points)
- f. single crystal silicon
- g. silicon substrate
- h. control processor section
- i. memory section
- j. electrical source and cooling section



(a) イメージプロセッサ　　　(b) モニタTV

Figure 7 Outline of Layered Multifunctional Integration Element

Key: a. photoelectric conversion b. series processing
c. main processor d. memory
e. electrical source and cooling
f. light input pattern
g. silicon substrate
(a) image processor (b) monitor TV

4. Details and Objects of Research and Development /41

The main points of design and evaluation technology for special 3 dimensional circuit structures are process technology and layering, including silicide, etc. electrode formation and surface flattening, and layered structure formation technology, including laser and electron beam annealing. In particular, heat measurements and wiring between layers are important problems for realizing the aforementioned elements. Moreover, of these basic technologies, lithography technology and beam process technology employing light emitted from accelerated electrons (SOR) are very important.

The basic properties necessary in 3 dimensional circuit elements are shown in Table 2. The various basic technologies necessary for realizing elements with these properties are being established in this research and development.

It is estimated that if this type of 3 dimensional circuit element can be realized, it will have a large impact on various industrial devices, such as robots, etc., and medical equipment because the current medium sized electric devices will be made smaller and equipment functions will be improved. This research and development will be carried out for 10 years until 1990.

5. 3 Dimensional Circuit Element Research and Development System

Research and development on layered high density integration elements and layered multifunctional integration elements has been recontracted to Nippon Denki, Fukashi Denki, Toshiba, Mitsubishi, Matsushita Denshi, Mitsuyo, and Shyābu*. The Electronics Technology Research Lab is in charge of 3 dimensional circuit element basic technology.

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*Translator's note: term unknown; transliteration of Japanese phonetic characters.

Table 2 Properties of 3 Dimensional Circuit Elements

type	desired properties
layered high density integration element technology	with 8-10 or more layer integration 16 M bits/chip memory function integration element 50 k gates/chip logic function integration element
layered multifunctional integration element technology	with 5 or more layer integration large capacity data processing I/O intelligent terminal intelligent image processor including sensor functions (standard of 0.1-10 M elements/chip integration)

Environment Resistant Element Research and Development

1. Necessity of Research and Development

(1) The necessity of LSI circuits that can withstand use in space has gradually increased with the development of large, high precision, multifunctional satellites for the development of a Japanese space program. Research and development on integrated circuit elements for satellites to be launched in the 1990's must begin now. Moreover, research is important when we consider that it will cost 15,000,000,000 to 20,000,000,000 yen to launch 1 satellite.

(2) Improvement of nuclear reactor operation efficiency and safety are important from the point of energy conservation. In order to achieve this, reactor observation, control and repairs must be improved and automation and surrounding industry safety improvement are essential. The most important problems are the improvement of circuit radioactivity resistance and heat resistance. In addition, the development of radioactivity resistant elements is in strong demand from the points of developing radioactive devices for use in medicine and inspections.

(3) The realization of integrated circuits that can be used with automobiles, aircraft, robots, etc. exposed to high temperatures and mechanical stress will help to improve Japanese production technology. Moreover, these circuits are also important from the points of realizing an unpolluted society and domestic countermeasures against resource and energy shortages.

(4) Environment resistant elements are being studied in the U.S. be T.I., Hughes, and Rockwell. This technology was advanced to a considerable degree with the Apollo designs and research continued afterwards. Moreover, research is also being carried out in France and Germany. However, the details of studies in both countries are unclear because of military secrecy. Moreover, since we do not anticipate obtaining information from foreign countries in the future, Japan will have to research and develop environment resistant elements on her own.

2. Van Allen Belts and Satellites

As shown in Figure 8, radioactive belts, or that is, Van Allen belts, which are held by the earth's magnetic field, are present 1,000 to 60,000 km above the earth. Geostationary satellites are lauched into a geostationary orbit of about 35,000 km and therefore, are affected by the Van Allen belts. Protons and electrons emitted from the sun repeat spiral shaped movements along the lines of magnetic force in the Van Allen belts. Elements become damaged when these protons and electrons shine on the satellites. Because the walls of large satellites are aluminum plates with a thickness of 1 mm or less, electrons and protons with high energy penetrate the walls and elements are directly hit by primary radioactivity, as shown in Figure 8. However, the majority of the electrons and protons collide with the walls to produce secondary radioactivity, such as rays, etc. It can be said that for the most part, geostationary satellites are affected by 10^5 rad* of radioactivity per year. /42

3. Radioactive Destruction Mechanism

The mechanism of radioactive destruction when α ray, γ ray, and neutron radiation hit MOS transistors is shown in Figure 9.

(1) Effects from α Rays

Since rays have a very large energy, they immediately produce many electrons and holes when they hit a transistor just one time. Of these, electrons enter a drain to produce a voltage error. For instance, 5 MeV α rays run about 30 μm in silicon and during this time, produce 1.4×10^6 electrons. This is equal to a pulse current of about 2 μA (provided that they accumulate in 100 ns). This α ray destruction is as effective as the electrons are small. Operation error of a 16 k bit CRAM with rays from a ceramic package was a problem a few years ago. However, this has recently been solved with improved packaging materials. Moreover, α rays are easily absorbed and therefore, it seems that α rays which hit chips from the outside can be almost completely absorbed when a thin plastic protective film is coated on the chip surface. Recovery from errors due to α rays is quick because they are primary and therefore, they are called soft errors.

*Rad: equal to 100 erg energy absorption per 1 g with a standard unit of absorbed rays. The amount of absorption varies with the substance, even when the amount of irradiation is the same.

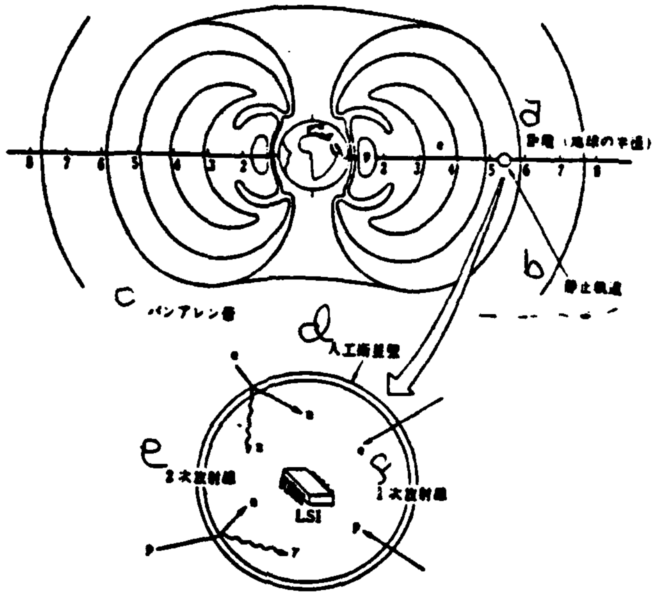

Figure 8 Radioactivity Hitting a Satellite

Key:
- a. distance (radius of earth)
- b. geostationary orbit
- c. Van Allen belts
- d. satellite walls
- e. secondary radioactivity
- f. primary radioactivity

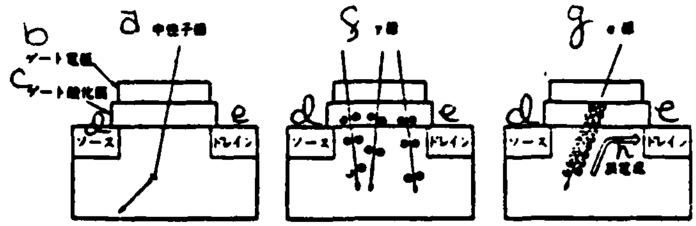

Figure 9 Mechanism of MOS Transistor Damage by Radioactivity

Key: a. neutron rays b. gate electrode
c. gate oxide film
d. source e. drain
f. γ rays g. α rays
h. current error

(2) γ Rays

In the case of γ rays, energy is lower than with α rays, and therefore, the charge produced by 1 strike is small. However, the probability that γ rays will hit the transistor is greater and it is difficult to prevent these rays from hitting even a transistor since the collision cross section is small. As shown in Figure 9, a positive charge is produced when γ rays strike. However, in the diagram, the positive charge produced at the gate oxide film is easily trapped. Therefore, when many γ rays hit the transistor, the threshold voltage (V_{tk}) shifts and operation error occurs. Release of this trapped charge takes time and therefore, semipermanent damage occurs. Moreover, since the oxide film of the gate plays a basic role in operation, MOS transistors are weak with regard to γ rays, and therefore, bipolar devices seem to be more effective from this point.

(3) Neutron Rays

When neutron rays strike the elements and collide with Si atoms, the Si atoms scatter and lattice defects and nucleus conversion of $Si^{30} \rightarrow P^{31}$ occur. In this case, damage is permanent. Bipolar transistors have few carrier devices, and therefore, are weak against this type of lattice defect. A degree of self recovery from this type of lattice defect is possible, and it is said that these effects are greater with GaAs than with Si.

4. General Radioactivity Resistance Measures

Silicon elements of MOS type SOS are structurally strong with regard to semiconductor radioactivity resistance. In this case, it is important that a regeneration layer is lost because the charge drop in the oxide film is controlled by cryogenic processing and because of the Si inpura* solid epi* to the Si sapphire interface, etc. Moreover, since the GaAS MESFET does not have and oxide film and when heated to about 250 ^{o}C after deterioration, it recovers from lattice defects, GaAS MESFET is said to be effective against radioactivity.

In addition, it is also necessary to detect operation errors and damaged elements and to use compensating circuits.

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*Translator's note: terms unknown; transliteration of Japanese phonetic characters.

5. Development Objectives and Applications

Environment resistant element research and development objectives and applications are shown in Figure 10.

With regard to plans for research and development of environment resistant elements, the radioactivity resistance with a degree of integration of 3×10^4 transistors/chip or more using a Si element, which is the most advanced integration technology used in space at the present time, is 10^5 Rad (the objectives of the VHSIC plan of the U.S. is 10^4). Furthermore, GaAs is used as a nuclear reactor element, which requires an even higher radioactivity resistance (10^7 Rad or more). Since analogue IC is anticipated, the degree of integration has been made 30 or more.

Moreover, SiC is being used as the heat resistant elements in automobiles, plants, etc. The objective is an element that can withstand 300° C.

With regard to mechanical stress resistance of these elements, vibration resistance is 40 G or more and impact resistance is 3,000 G or more with both elements (respectively, 30 G and 1,500 G according to MIL (U.S. Army) standards).

6. Details and Period of Research and Development

I^2L research and development is being carried out on bulk Si and SOS MOS integrated circuits and bipolar devices. Important research and development on high precisison technology for planning and special environments are being carried out in this project in order to obtain an element manufacturing technology and packaging technology. In particular, the establishment of a testing and evaluation basic technology is very important. The research and development period is the 8 years up to 1988.

7. Environment Resistant Element Research and Development System

Research and development of silicon element technology (MOS and bipolar) and one radioactivity resistant compound semiconductor (GaAs) element technology has been recontracted to Toshiba, Hitachi and Mitsubishi. The Electronics Technology Research Lab is in charge of heat resistant compound semiconductor (SiC) element technology and evaluation and testing technology.

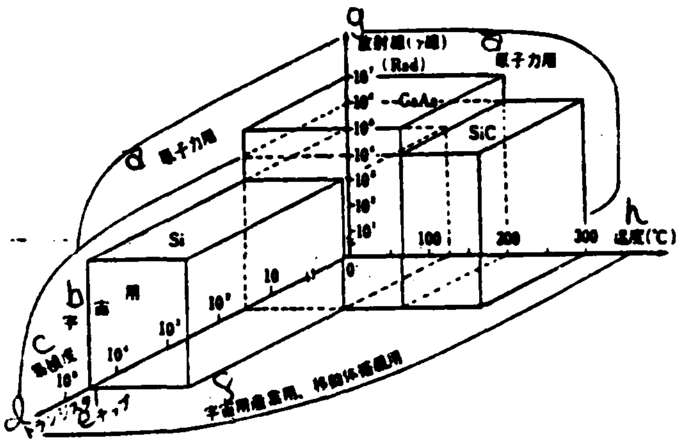

Figure 10 Development Objectives and Applications of Environment Resistant Elements

Key: a. for nuclear power b. for space
c. degree of integration
d. transistor e. chip
f. space industry, for loading moving bodies
g. radiation (γ rays)
h. temperature (^{o}C)

Many countries are now carrying out research and development on the 3 new functional elements introduced above. Since this field is one in which research develops quickly, it will be necessary to take a second look at the objectives of the research and to develop flexible research and development plans.

Bibliography

[1] Japanese Electronics Industry Association: "Research Report on Semiconductor Ultralattice Elements", 56-M-176.

2) H. Sakaki : J. J. A. P., Vol. 19, No. 12, 735 ([illegible])
3) H. Kroemer : Proc. 12 th conf. S. S. D., Tokyo ([illegible]); J. J. A. P., Vol. 20, 9 (1981)
4) M. Heiblum : S. S. E. Vol. 24, [illegible] ([illegible])

Circuit logic and memory elements are 3 dimensionally arranged and connected to each semiconductor active layer,

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